

## 1 WHAT IS CLAIMED IS:

1. A method of forming a dense reinforcement-containing bulk solidifying amorphous alloy -matrix composite material comprising:

5 providing a feedstock of a bulk solidifying amorphous alloy having the capability of retaining an amorphous state when cooled from above its melting temperature at a critical cooling rate of no more than about 500° C/s;

dispersing a plurality of pieces of a reinforcement material throughout the bulk solidifying amorphous alloy feedstock to form a mixture of reinforcement material and bulk solidifying amorphous alloy feedstock;

10 densifying the mixture by applying a force to the mixture at a temperature above the melting temperature of the bulk solidifying amorphous alloy;

cooling the densified mixture below the glass transition temperature of the bulk solidifying amorphous alloy to form a solidified composite material;

15 reheating the solidified composite mixture to a forming temperature;

forming the reheated composite mixture into a desired shape at the forming temperature; and

quenching the reheated mixture to an ambient temperature to form an amorphous alloy -matrix composite material.

20 2. The method as described in claim 1 wherein the cooling of the densified mixture is carried out at a cooling rate no less than the critical cooling rate such that the bulk solidifying amorphous alloy matrix of the solidified composite material is substantially amorphous, and wherein the forming temperature is between the glass transition temperature of the bulk solidifying amorphous alloy and the crystallization temperature of the bulk solidifying amorphous alloy.

30 3. The method as described in claim 1 wherein the cooling of the densified mixture is carried out at a cooling rate less than the critical cooling rate such that the bulk solidifying amorphous alloy matrix of the solidified composite material is substantially crystalline, wherein the forming temperature is greater than the melting temperature of the bulk solidifying amorphous alloy, and wherein the quenching of the reheated mixture is carried out at a cooling rate no less than the critical cooling rate such that the amorphous alloy -matrix composite material is substantially amorphous.

35 4. The method as described in claim 1 wherein the bulk solidifying amorphous alloy has a supercooled liquid regime of larger than 60 °C.

- 1        5.        The method as described in claim 1 wherein the bulk solidifying amorphous alloy has  
a supercooled liquid regime of larger than 90 °C.
- 5        6.        The method as described in claim 1 wherein the bulk solidifying amorphous alloy is  
described by the molecular equation:  $(\text{Zr,Ti})_a(\text{Ni,Cu, Fe})_b(\text{Be,Al,Si,B})_c$ , where a is in the  
range of from 30 to 75, b is in the range of from 5 to 60, and c in the range of from 0 to 50 in  
atomic percentages.
- 10       7.        The method as described in claim 1 wherein the bulk solidifying amorphous alloy is  
described by the molecular equation:  $(\text{Zr,Ti})_a(\text{Ni,Cu})_b(\text{Be})_c$ , where a is in the range of from 40  
to 75, b is in the range of from 5 to 50, and c in the range of from 5 to 50 in atomic  
percentages.
- 15       8.        The method as described in claim 1 wherein the bulk solidifying amorphous alloy is  
described by the molecular equation:  $(\text{Zr})_a(\text{Nb,Ti})_b(\text{Ni,Cu})_c(\text{Al})_d$ , where a is in the range of  
from 45 to 65, b is in the range of from 0 to 10, c is in the range of from 20 to 40 and d in the  
range of from 7.5 to 15 in atomic percentages.
- 20       9.        The method as described in claim 1 wherein the bulk solidifying amorphous alloy  
contains a ductile crystalline phase precipitate.
- 25       10.       The method as described in claim 1 wherein the reinforcement material is stable at  
temperatures at least greater than the melting temperature of the bulk solidifying amorphous  
alloy.
- 30       11.       The method as described in claim 1 wherein the reinforcement material contains at  
least one refractory metal selected from the group consisting of tungsten, molybdenum,  
tantalum, niobium and their alloys.
- 35       12.       The method as described in claim 1 wherein the reinforcement material contains at  
least one material selected from the group consisting of SiC, SiN, BC, TiC, WC, SiO<sub>2</sub>,  
diamond, graphite and carbon fiber.
13.       The method as described in claim 1 wherein the reinforcement material takes a form  
selected from the group consisting of wire, fiber, loose particulate, foam and sintered  
preforms.

1 14. The method as described in claim 1 wherein the packing density of the pre-densification mixture is least 50 %.

5 15. The method as described in claim 1 wherein the step of applying a force occurs under vacuum.

16. The method as described in claim 1 wherein the step of applying a force includes extruding the mixture at a temperature above the melting temperature of the bulk-solidifying amorphous alloy.

10 17. The method as described in claim 1 wherein the step of applying a force includes applying a hydro-static pressure to the mixture at a temperature above the melting temperature of the bulk-solidifying amorphous alloy.

15 18. The method as described in claim 1 wherein the step of applying a force includes carrying out a hot-isostatic process on the mixture at a temperature above the melting temperature of the bulk-solidifying amorphous alloy.

20 19. The method as described in claim 1 wherein the step of applying a force forms a densified mixture having a packing density of greater than 99 %.

20. The method as described in claim 1 wherein the reinforcement material comprises a volume fraction of the solidified composite material of greater than 75 %.

25 21. A reinforcement-containing bulk solidifying amorphous alloy-matrix composite material having a packing density of at least 99% and comprising:

a mass of a bulk-solidifying amorphous alloy characterized by the ability to retain an amorphous state when cooled from its melt at a critical cooling rate of no more than about 500° C/s; and

30 a plurality of reinforcement pieces dispersed throughout the mass of the bulk solidifying amorphous alloy;

wherein the reinforcement material comprises at least 75% of the bulk solidifying amorphous alloy-matrix composite material by volume.

35 22. The reinforcement-containing bulk solidifying amorphous alloy-matrix composite material described in claim 21 wherein the reinforcement material contains at least one refractory metal selected from the group consisting of tungsten, molybdenum, tantalum, niobium and their alloys.

1      23.    The reinforcement-containing bulk solidifying amorphous alloy-matrix composite material described in claim 21 wherein the reinforcement material comprises 85% by volume of the composite material.

5      24.    The reinforcement-containing bulk solidifying amorphous alloy-matrix composite material described in claim 21 wherein the composite material is shaped into an article.

10      25.    The reinforcement-containing bulk solidifying amorphous alloy-matrix composite material described in claim 24 wherein the article is a cylindrical rod with an aspect ratio of greater than 10.

15      26.    The reinforcement-containing bulk solidifying amorphous alloy-matrix composite material described in claim 24 wherein the article is a cylindrical rod with an aspect ratio of greater than 10 and with a diameter of at least 10 mm.

20      27.    The reinforcement-containing bulk solidifying amorphous alloy-matrix composite material described in claim 24 wherein the article has a measurement of at least 0.5 mm in all dimensions.

25      28.    The reinforcement-containing bulk solidifying amorphous alloy-matrix composite material described in claim 24 wherein the article is a disc-shaped object with an aspect ratio (height/diameter) of less than 0.1.

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